Product Application Instructions: Castable Refractories

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1. Scope of Application

The procedures outlined in this document apply to the placement of both dense and lightweight (insulating) monolithic refractories across the PCOCast and PCOFlow product portfolios. These instructions cover castables engineered with hydraulic-setting bonding systems, including RC, MC and LC cement-bonded formulations, as well as next-generation sol-gel and colloidal-binder systems utilized in the NxGel, Sol, Gel, and ISO product series.

The guidelines address all phases of installation, including mixing, casting, consolidation, initial set development, curing, and controlled dry-out, in accordance with industry best practices for monolithic refractory linings.

Where individual installation instructions have been issued for a specific product, such instructions shall take precedence over the provisions of this document.

For any installation-related inquiries, troubleshooting needs, or application-specific guidance, please contact the PCO Technical Department at: konsultacja@pco.pl.

2. Glossary

Dense refractory castables – castable refractory materials with a bulk density typically above 2.0 g/cm³. They are designed to provide high mechanical strength, abrasion resistance and are most commonly used as the working lining of refractory linings.

Lightweight (insulating) refractory castables – monolithic lightweight materials characterized by a bulk density generally below 1.5 g/cm³. These castables are engineered primarily for low thermal conductivity and are commonly employed as back-up linings behind dense refractories to reduce heat loss and shell temperatures. Under suitable service conditions—typically involving moderate mechanical loads, limited abrasion, and controlled thermal cycling—they may also function as primary (working) linings.

Mixing water – the amount of water added to the dry mix in order to obtain a flowable castable consistency suitable for casting.

Sol binder – A special nano silica-contained liquid binder employed in Sol systems as a full replacement for conventional mixing water. It facilitates the preparation of a castable mix with the required rheology, ensuring proper flowability, self-leveling behavior, and casting performance during installation.

Shutter – a temporary structure (typically made of wood or steel) into which fresh castable is poured and retained until it has set and reached sufficient strength

3. Storage

3.1. Storage location and conditions

Castable materials are supplied in 25-kg paper bags or in big bags placed on pallets. All materials must be stored in a dry, well-ventilated area to prevent moisture pickup and premature hydration. If the packaging is additionally wrapped in plastic foil, adequate air circulation beneath the pallet must be maintained to avoid moisture condensation inside the packaging. Storage in environments with elevated humidity levels is not recommended, as it may adversely affect the shelf life and performance of the castables.

The recommended storage temperature ranges from 10°C to 25°C. Although storage outside this range could be acceptable, the castable must be brought to the recommended temperature interval prior to installation to ensure correct workability and installation performance — see Section 5.4.

Improper storage conditions may negatively affect the handling properties and performance of the material during installation or service.

3.2. Pallet stacking

Pallet stacking is allowed only when both the supporting surface and the pallet tops are flat, level, and structurally stable to safely carry the load. No more than two pallet layers should be stacked, as higher stacking may compromise material integrity and handling safety. Furthermore, do not place pallets containing dense castables on top of pallets holding lightweight castables, as the higher load may deform or damage the lower-density packaging.

As a good practice, materials of the same grade should be consumed in the order of delivery, in accordance with the FIFO principle (First In – First Out).

3.3. Shelf life

The shelf life of refractory castables shall be as stated in the applicable Technical Data Sheet. For most materials, the declared shelf life is typically 6 to 24 months from the date of manufacture, which is marked on the side wall of the bag or on the pallet identification label.

An overdue material exhibited a prolonged setting time, changes in consistency, and reduced mechanical performance.

Materials shall be consumed in accordance with the First-In, First-Out principle, ensuring that the oldest batches are used first.

In cases where the declared shelf life has expired, the material shall not be released for installation until verification testing has been conducted and compliance with the specified performance requirements has been confirmed.

To prevent premature hydration or contamination, packaging should be consumed immediately after to be opened.

4. Shutter, joints and anchoring systems

4.1. Shutter

Shuttering used for casting process shall be constructed from non-absorbent materials with sufficient mechanical strength to maintain dimensional stability throughout placement and vibration of the castable. Common solutions include varnished plywood of approximately 18 mm thickness or steel framed-cavity, both of which provide adequate rigidity and resistance to moisture uptake.

Prior to casting, the shuttering surfaces shall be cleaned and uniformly coated with a thin layer of release lubricant or mould-release agent. This preparation facilitates demoulding after curing and promotes the formation of a smooth, defect-free lining surface.

The shuttering assembly shall be tight and sealed. This requirement is essential, as any leakage during vibration may allow mixing water and fine particles to escape, leading to segregation of the castable.

4.2. Steel anchoring

Refractory lining configurations require the installation of steel anchoring systems. Anchors shall be manufactured from appropriate steel grades suitable for the specified service conditions and shall be securely fixed to the supporting structure onto which the monolithic lining is to be applied.

The anchor type, quantity, and spacing shall be determined based on the selected refractory material, the lining design, and the anticipated operating environment. In all cases, the lining designer's specifications and drawings shall take precedence and shall be strictly followed.

Prior to placement of the castable, the quality of anchor welds should be verified, for example by performing a bend test in accordance with ISO 14555 standard. A correctly executed weld shall permit the anchor to be bent to approximately 60° and subsequently return to its original position without evidence of cracking or weld failure.

When using steel anchors, the application of plastic expansion sleeves (caps) is recommended.

4.3. Ceramic anchors

Ceramic anchors can withstand substantially higher service temperatures than steel anchors, making them suitable for installation in areas of the refractory lining subjected to elevated thermal loads.

When ceramic anchors are employed, an appropriate expansion allowance shall be provided. This may be achieved by applying a bituminous coating of approximately 1-2 mm thickness or by wrapping the anchor with ceramic paper of equivalent thickness.

During installation, care shall be taken to ensure that the original external comb-shaped geometry of the anchor is maintained, as alteration of the profile may adversely affect its anchoring performance.

5. Preparation for installation

5.1. Personal protective equipment (PPE)

During installation process, appropriate personal protective equipment shall be worn, selected according to the specific work tasks and prevailing ambient conditions. As a minimum, safety goggles or glasses, protective gloves, dust masks or respirators, and suitable protective, high visibility clothing should be used.

5.2. Tools

All tools, including the mixer pan, transport containers, trowels, shovels and vibrator needles, must be dry and free from contamination.

Any residues left on tools may negatively affect the setting time or mechanical properties of the castable.

Prior to starting installation, the operating instructions of the equipment, especially mixers and vibrators, shall be carefully reviewed.

5.3. Material requirement

The amount of dry castable required to produce 1 m^3 of refractory lining is specified in the Product Technical Data Sheet. When planning material consumption, it is recommended to include an additional allowance of approximately 5% to compensate for losses caused by, among others, accidental bag damage, spillage during handling and residual material left in bags or the mixer. In the case of difficult working conditions or applications carried out at a significant distance from the mixing area, this allowance should be increased to 10% or more.

5.4. Application temperature

The temperature of the bagged material, mixing water, and surrounding environment has a direct and significant effect on the mixing characteristics and setting behavior of refractory castables. Lower temperatures may cause to delay the setting process, whereas elevated temperatures can accelerate setting process.

For castable preparation, the temperature of both the dry mix and the mixing water shall be maintained within the range of 10–25°C.

The use of contaminated water may negatively affect the setting time and mechanical properties of the castable.

During winter conditions, when temperature of material may be below the recommended temperature range, bags of castable shall be stored in a heated area or under protective tent at a minimum temperature of 15°C for at least 48 hours before installation.

During summer or high-temperature storage conditions, the material shall be placed in a covered, shaded area for a minimum of 48 hours prior to use. In addition, shuttering surfaces should be cooled by light water misting, ensuring that no water enters the mould cavity.

When working at elevated temperatures, the available time for placing the castable is significantly reduced.

Casting and holding the castable until complete setting shall be carried out at an ambient temperature between 10°C and 25°C. In winter condition if the castable freeze before setting is complete, the final strength may be reduced by up to 50% or more. Therefore, freezing conditions must be avoided until the lining has been fully dried and heated up.

As the amount of water added to a refractory castable has a greater influence on its properties than any other single factor, it must be accurately measured.

If curing takes place at elevated temperatures, it is recommended to cover the castable surface with a suitable material and periodically moisten it with water.

6. Preparation of the mix

6.1. Mixing water

6.1.1. Quality of mixing water

Water used for castable preparation shall be clean and of potable water quality. The pH value shall be within the range of 6–8, and the recommended water temperature is 10–25°C. The use of seawater or contaminated water containing, among others, sulphur compounds, chlorine, magnesium, ammonia or carbonates in concentrations exceeding 1000 ppm, as well as water containing sugars or suspended solids, is strictly prohibited.

6.1.2. Amount of mixing water

The amount of mixing water required for a given castable type is specified in the Product Technical Data Sheet, and any deviation from these values is permitted only upon explicit instruction from a PCO representative.

When preparing the mix, it is recommended to initially add approximately 80–90% of the specified water quantity, and then, while continuing mixing, add the remaining water gradually in small portions until the correct consistency is achieved. The following good practices are recommended:

- **for lightwieght castables** – the amount of added water shall correspond strictly to the values stated in the Product Technical Data Sheets;
- **for dense castables** –the minimum amount of water required to place the material shall be used and shall not exceed the value stated in the Product Technical Data Sheets. The best method for determining the correct water content for dense castables is the "ball-in-hand" test, described in Section 6.5.

6.2. Type of mixer

For dense castables of the PCOCast, NxGel, Sol and Gel series, as well as PCOCast ISO lightweight castables, the use of counter-current (pan) mixers is recommended (Figure 1).

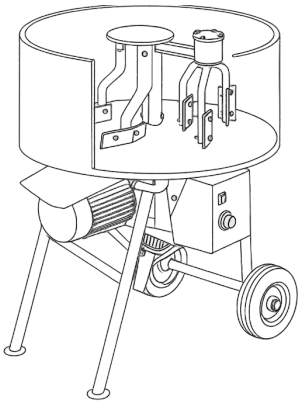

Figure 1. Counter -current mixer

6.3. Mixing procedure

Mixing consists of combining the dry components with water or binder into a homogeneous mass. The mixing procedures for individual product groups are described below.

⚠	It is not permitted to mix more material than can be cast within 20 minutes from the start of mixing, nor to mix different castable types together.

6.3.1. Mixing procedure for PCOCast ISO:

1. Charge the dry material into the mixer pan and dry-mix for 30–60 seconds;
2. Add the recommended amount of mixing water (see Product Technical Data Sheet);
3. Mix with water for 1.5 to 2 minutes;

6.3.2. Mixing procedure for PCOCast and PCOFlow:

1. Charge the dry material into the mixer pan and dry-mix for 30–60 seconds;
2. Add 80–90% of the recommended mixing water (see Product Technical Data Sheet);
3. Mix with water for:
   a. Conventional and medium-cement PCOCast dense castables: 2–5 minutes;
   b. Low-cement and ultra-low-cement PCOCast castables: 3–5 minutes, until a homogeneous mass is obtained;

6.3.3. Mixing procedure for Gel / NxGel products:

1. Charge the dry material into the mixer pan and dry-mix for 30–60 seconds;
2. Add 80–90% of the recommended mixing water (see Product Technical Data Sheet). Add the remaining water, if required, gradually during mixing;
3. Mix for 3–5 minutes until a homogeneous mass is obtained.

6.3.4. Mixing procedure for Sol products:

1. Charge the dry material into the mixer pan and dry-mix for 10–30 seconds;
2. Add the recommended amount of Sol binder;
3. Mix with the binder for 3–5 minutes until a homogeneous mass is obtained;

⚠	Only the Sol binder supplied with the product shall be used for Sol materials. The addition of water may adversely affect setting time and service properties.

⚠	Products from the Gel and Sol series achieve their proper consistency only after several minutes of mixing with water or binder. No additional water or binder shall be added in order to prematurely liquefy the mix!

6.4. Addition of fibres

If steel or polypropylene fibres are to be added to the castable, they shall be introduced only after the dry mix has been combined with water. Fibres shall be dosed slowly and evenly, by sprinkling them directly onto the surface of the mix in the mixer pan. If fibres are already included in the dry mix, the amount of mixing water shall be calculated based on the castable mass excluding fibres, not on the total bag weight. The fibre weight must be deducted from the bag weight prior to calculating the required water quantity.

⚠	The addition of fibres reduces the flowability of the mix, and the mixing water content must not be increased to compensate for this effect.

6.6. Consistency control

Mixing shall continue until a homogeneous mass is obtained. The consistency may be assessed using the "ball-in-hand" test (Figure 2). A ball approximately the size of a fist is formed in the hand and gently tossed to a height of 2–5 cm. After being caught, the ball should retain the shape of the hand, not disintegrate, and not flow between the fingers. Disintegration indicates insufficient water or binder, while material flowing between the fingers indicates excessive water content. For lightweight castables, which typically contain higher water amounts, slight flow is acceptable. This method is not suitable for thixotropic mixes, vibrated castables or low-cement systems.

Figure 2. Mass consistency test.

It is recommended that the sample for the ball test be taken from material discharged into a bucket, rather than directly from the mixer. If sampling directly from the mixer is unavoidable, it must be done only with the mixer switched off and protected against accidental start-up.

Both over-mixing and under-mixing shall be avoided. Excessive mixing causes heating of the mix, which shortens the setting time, while insufficient mixing may result in inhomogeneous structure and reduced strength. For mixers with bottom discharge, at least the first two buckets shall be discarded to clean the discharge gate. The recovered material may be immediately returned to the mixer and re-mixed. After each mixing cycle, the discharge gate shall be thoroughly cleaned to prevent accumulation of hardened material.

The mixer and all casting tools shall be kept clean at all times, as residues of previously mixed materials may cause accelerated setting or reduced final strength. Periodic cleaning of the mixer between batches is also recommended to prevent the build-up of hardened castable.

7. Casting

Casting operations of the prepared refractory mix include several key activities:

1. placing and compacting the fresh mix within a maximum of 20 minutes from discharge from the mixer;
2. carrying out the work in a manner that minimises segregation of mix components;
3. filling all voids, in particular around structural elements and in corners, and removing entrapped air;

Once application has started, it shall be carried out continuously without interruptions until the entire lining section or panel has been completed.

Before mixing and casting operations commence, it shall be ensured that:
- a sufficient quantity of dry material and mixing water is available at the job site,
- all required tools and equipment are prepared,

so that the entire cast section can be completed without interruptions and within no more than 20 minutes from placement of the first batch.

7.1. Vibration during casting

Compaction of dense castables from the PCOCast, Gel, Sol and NxGel series shall be carried out using medium- or high-frequency vibrators, applied either internally or externally. The use of high-frequency vibration is advantageous, as it allows for the use of lower water content, resulting in higher strength, density and abrasion resistance The best results are obtained with internal (immersion) vibrators, which provide optimal compaction and strength of the castable and facilitate material flow around anchors and into difficult-to-access areas. The vibration time shall not exceed 2–3 minutes.

Excessive vibration must be avoided, as it may lead to segregation of water and aggregates, resulting in weakened castable properties.

Insulating castables shall be compacted gently, using a medium-frequency vibrator or manually with a rod. Vibration or compaction shall continue until the mix settles, the surface develops a wet appearance, and air bubbles cease to appear.

For best results, the vibrator shall be inserted vertically, to a depth not exceeding 35 cm, and then withdrawn slowly to avoid the formation of voids or channels. If cavities remain in the mix after vibrator withdrawal, this indicates that the mix is too stiff.

When compacting near anchors or other structural elements, fresh mix shall be fed from one side only, allowing the vibrator to distribute the material around and beneath the obstruction, thus eliminating the risk of air pockets. For deep recesses requiring placement in multiple layers, the vibrator tip shall penetrate through the fresh layer into the previously placed layer, ensuring a monolithic structure without delamination.

Castables from the PCOFlow series do not require vibration.

7.2. Multi-layer linings

If a new castable layer is applied onto a previously cast layer, the underlying surface shall be protected with an impermeable membrane, such as plastic foil, to prevent premature moisture loss from the fresh mix into the substrate layer. The membrane shall be made of a material that burns out at low temperature, already at the beginning of the drying cycle. Alternatively, the substrate surface may be lightly moistened by gentle water spraying.

When casting sections containing anchors, the anchors shall be thoroughly cleaned prior to placement of the subsequent castable layer.

Under no circumstances shall a subsequent layer be applied before the previous layer has been fully completed and properly set.

7.3. Surface finishing

When finishing the exposed castable surface to the required height or shape, excessive trowelling shall be avoided. Over-finishing forces water to the surface and creates a thin, cement-rich layer, which is prone to spalling under cyclic heating and cooling. In addition, excessive finishing seals the surface, slowing down moisture release during drying.

8. Curing

After completion of casting, a curing process shall be carried out to ensure proper hydration of the binder and to prevent premature moisture loss. Excessively rapid evaporation of moisture from fresh castable before completion of the setting reactions leads to a reduction in final strength.

After casting, the castable shall remain in the shutter for a minimum of 24 hours. During this period, the surface of the castable shall be kept moist by means of light water spraying, covering with plastic foil or other evaporation-limiting materials.

In the case of enclosed components (e.g. ducts, small vessels), the space may be sealed tightly to retain moisture inside.

For outdoor installations, the castable surface shall be protected against direct sunlight until the curing process has been completed.

After the initial 24-hour curing period under moist conditions, the shutter may be removed, taking care not to damage the refractory lining.

If the castable sets excessively slowly or too rapidly, the PCO Technical Department must be contacted immediately. Following consultation, setting accelerators or retarders may be applied. The independent selection and use of setting modifiers is not recommended, as improper selection or overdosing may permanently and adversely affect the service properties of the castable.

9. Drying and heat-up

9.1. Free drying

After completion of curing, the castable lining shall be subjected to free drying at an ambient temperature

of at least 10°C for the longest possible period, but not less than 24 hours. The purpose of this stage is to stabilise conditions prior to controlled drying and to reduce the amount of free water in the castable, the presence of which could otherwise lead to undesirable chemical reactions between the lining surface and the atmosphere.

The optimal solution is to carry out complete drying immediately after curing. If this is not possible, the lining must not be left in a closed, humid environment. Instead, adequate ventilation shall be ensured, for example by using forced air circulation with a fan, or preferably a hot-air blower. After completion of free drying, the lining shall be protected against contact with rain, as this could adversely affect its properties.

9.2. Initial heat-up

Prior to commissioning, all refractory castable linings must be thoroughly heated up.

The heating process shall be carried out in accordance with strictly defined heat-up rates and temperatures, which depend on the type and quantity of refractory castable used as well as on the total lining thickness. In general, the thicker the lining, the longer the drying and firing time required. Detailed heat-up guidelines are provided in Table 1 and Table 2.

Once the scheduled heat-up process has started, it shall not be stopped or interrupted. In the event of an interruption, the lining shall be kept warm. If cooling is unavoidable, it must be carried out slowly, and reheating shall follow the original heat-up procedure.
General rules for the initial heat-up of castable linings:

1. Ensure continuous air flow through the furnace or installation in order to remove released moisture;
2. Until a temperature of 650°C is exceeded, direct flame impingement from burners onto the lining surface shall be avoided;
3. Temperature fluctuations shall be kept to an absolute minimum.

Improper drying and heat-up may lead to explosive spalling or destruction of the refractory lining, posing a serious risk to health and life. It is strongly recommended that this process be carried out under the strict supervision of qualified personnel.

It is recommended to use the following heating schemes for the brickwork, depending on the type of material:
PCOCast and PCOFlow castables (RC, MC, LC systems):

Table 1. Heat-up recommendations for PCOCast and PCOFlow linings after casting

Lining thickness	Stage	Heating rate	Target temperature	Holding time at target temperature
up to 200 mm	I	10°C/h	150°C	20h
	II	15°C/h	650°C	15h
	III	50°C/h	above 650°C	–
above 200 mm	I	10°C/h	150°C	24h
	II	10°C/h	650°C	24h
	III	30°C/h	above 650°C	–

Gel, Sol and NxGel castables:

Table 2. Heat-up recommendations for Sol, Gel and NxGel linings

Lining thickness	Stage	Heating rate	Target temperature	Holding time at target temperature
up to 200 mm	I	15°C/h	180°C	20h
	II	30°C/h	1200°C	–
above 200 mm	I	10°C/h	180°C	25h
	II	30°C/h	1200°C	–